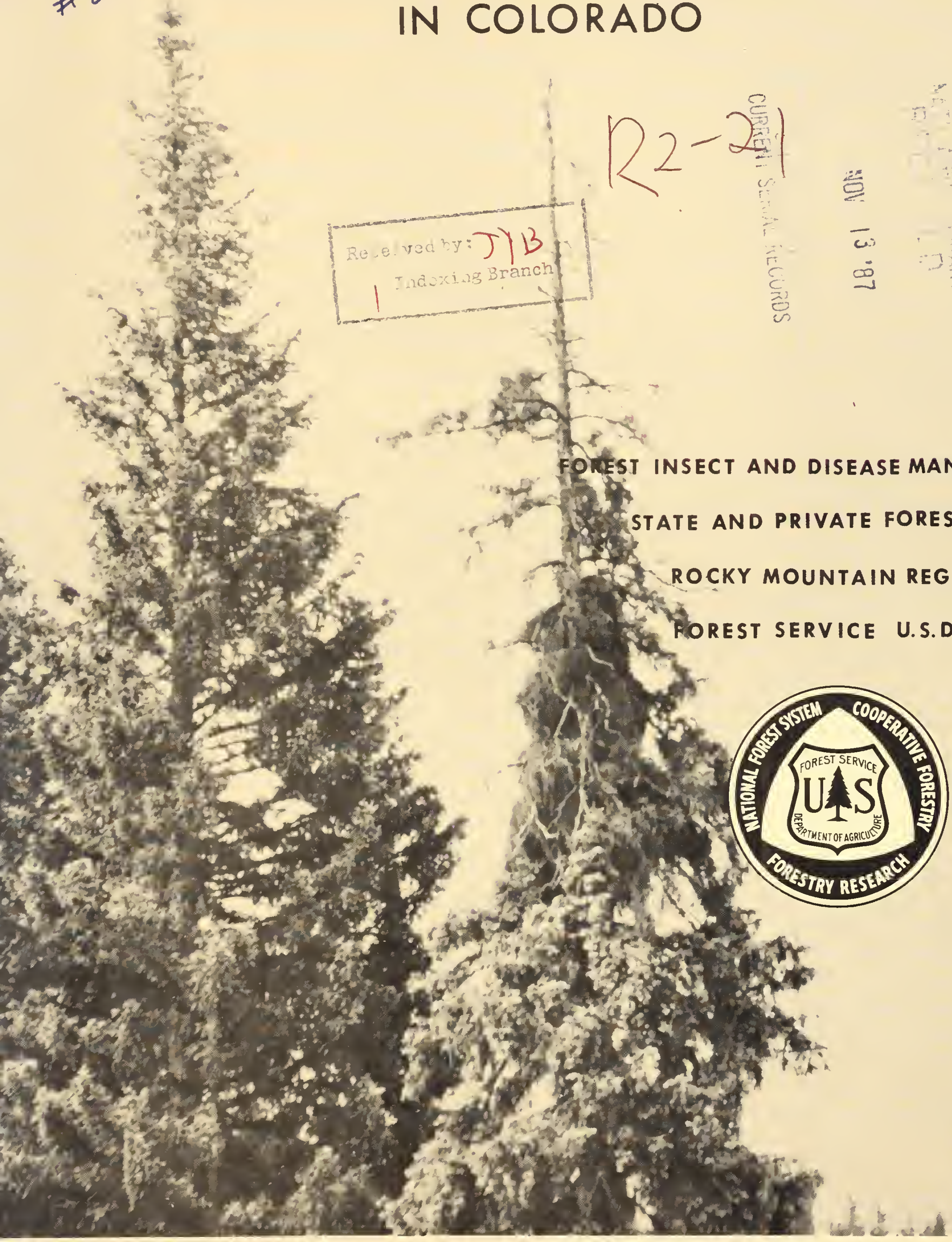
INCIDENCE AND DISTRIBUTION OF CONIFER BROOM RUSTS IN COLORADO



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INCIDENCE AND DISTRIBUTION OF CONIFER BROOM RUSTS IN COLORADO

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ABSTRACT

Surveys to determine the incidence and distribution of broom rust diseases caused by *Chrysomyxa arctostaphyli* on Engelmann spruce and *Melampsorella caryophyllacearum* on white fir and subalpine fir were conducted on 41 sites within six National Forests (Gunnison, Uncompahgre, San Juan, Rio Grance, White River, and Arapaho) in Colorado in 1978. On over 20,000 trees surveyed (and 79 square miles), average disease incidence was 4.2% and 2.3% for spruce and fir, respectively. Incidence varied widely among sites and tree age classes sampled. Rust incidence was lower on seedlings and saplings than on pole- and sawtimber-size trees. Spruce broom rust was common on most sites; highest incidence was 28% on pole-size trees of the Pine Ranger District, San Juan National Forest. Fir broom rust was common on white fir on the San Juan and Rio Grande National Forests, but rare on all sampled subalpine fir. More brooms were found on dead spruce and fir than on live trees. Almost half the brooms on diseased spruce and about one-fifth of the brooms on infected fir were within one foot of the bole. Most dead broomed spruce and fir trees had associated bole cankers. Trees with brooms near the bole and trees with bole cankers are affected by the disease more than trees with a few small branch brooms. Only a small percentage of broomed spruce and fir trees had spike tops or broken tops. Cutting guidelines for infested stands are presented.

INTRODUCTION

Broom rust diseases are common throughout the range of Engelmann spruce (*Picea engelmanni* Parry) and true firs, *Abies* spp., in Colorado. The diseases occur in stands of all ages and affect stand productivity, especially in areas currently under management or planned for intensive management.

Broom rust of Engelmann spruce is caused by the fungus *Chrysomyxa arctostaphyli* Diet.; true fir rust is incited by *Melampsorella caryophyllacearum* Schroet. These obligate parasitic rust fungi are host-specific and therefore not able to cross-infect conifer hosts (1, 3).

Spruce broom rust only occurs in North America (11). Other conifer hosts of *C. arctostaphyli* include Norway spruce (*P. abies* (L.) Karst.), white spruce (*P. glauca* (Moench) Voss), blue spruce (*P. pungens* Engelm.), black spruce (*P. mariana* (Mill.) B.S.P.), and Sitka spruce (*P. sitchensis* (Bong.) Carr.) (11, 12, 15). The most concentrated outbreaks of spruce broom rust occur in northern Arizona and southern Colorado on Engelmann spruce and blue spruce and in Alaska on black spruce and white spruce (11).

True fir species in the United States infected by *M. caryophyllacearum* include white fir (*Abies concolor* (Gord. & Glend.) Lindl.), subalpine fir (*A. lasiocarpa* (Hook.) Nutt.), Pacific silver fir (*A. amabilis* (Dougl.) Forb.), California red fir (*A. magnifica* A. Murr.), balsam fir (*A. balsamea* (L.) Mill.), and grand fir (*A. grandis* (Dougl.) Lind.) (3, 7, 8, 15). Fir broom rust reaches its greatest abundance in North America on subalpine fir in southern Idaho, northern Utah, and western Wyoming (6).

Bearberry or kinnikinnick (*Arctostaphylos ura-ursi* (L.) Spreng.) is the principal alternate host of the spruce broom rust fungus, but manzanitas (*Arctostaphylos* spp.) occasionally serve as hosts on the Uncompahgre National Forest (8, 15). Several mouse-eared chickweeds (*Cerastium* spp.) are principal alternate hosts of *Melampsorella* in Colorado; starwarts or chickweeds (*Stellaria* spp.) are also infected (8). Both broom rust fungi produce their conifer-infecting spores in early spring.

The most conspicuous symptom of these diseases is a proliferation of branches called a witches' broom (Figs. 1-2) (1, 14). Causal fungi become perennial and systemic within these brooms (15). In the summer, fungal fruiting occurs abundantly on the current-year needles of the broom (Fig. 2-C), which are etiolated, shorter, and thicker than healthy needles. Infected needles die and are shed

FIGURE 1

Engelmann spruce broom rust caused by
Chrysomyxa arctostaphyli.

A. Infected tree exhibiting characteristic spike top and branch mortality.

B. Broom near the bole of spruce. Such brooms may indicate heartrot.

C. Heavily infected young tree.


A
B
C

FIGURE 2

True fir broom rust caused by
Melampsorella caryophyllacearum.

A. Large witches' broom (arrow) on subalpine fir.

B. Trunk infection of white fir. Such brooms may provide infection courts for decay fungi as trees become large.

C. Aeciospore production by fir broom rust on subalpine fir. Fruiting occurs on current-year needles of the broom in the summer.

D. Fir broom rust on seedlings. (Brooms indicated by arrows)


A
B
C
D

in the fall. Brooms appear dead in the winter (15). Conifer brooms not caused by rusts, e.g. those incited by dwarf mistletoes, retain their normal dark-green color throughout the year and shed only a few needles in the fall. Broom rust infections are commonly associated with spike tops (Fig. 1-A), dead branches, bole deformations, cankers, and mortality (8, 15).

Damage caused by spruce and fir broom rust includes growth loss, bole deformations, cull, and mortality (8, 10). Presence of brooms near the trunk of infected trees (Figs. 1-B, 2-B) may indicate heartrot (4). Brooms and their associated cankers may serve as infection courts for decay fungi, such as *Fomes pini* (Thore) Lloyd and *Lentinus lepideus* Fr. (4). Peterson (8) found that a few brooms per tree can cause more than 20% reduction in diameter and height growth in spruce. Estimates of cull for spruce broom have been made (4); however estimates of mortality or growth reduction on a volume or area basis are not currently available (R. G. Krebill, *unpublished*).

Because of their conspicuous symptoms, broom rusts are often easily recognized by forest resource managers and several requests for more information on disease levels within areas under their jurisdiction have been received. These requests prompted surveys which were conducted during 1978 on several National Forests.

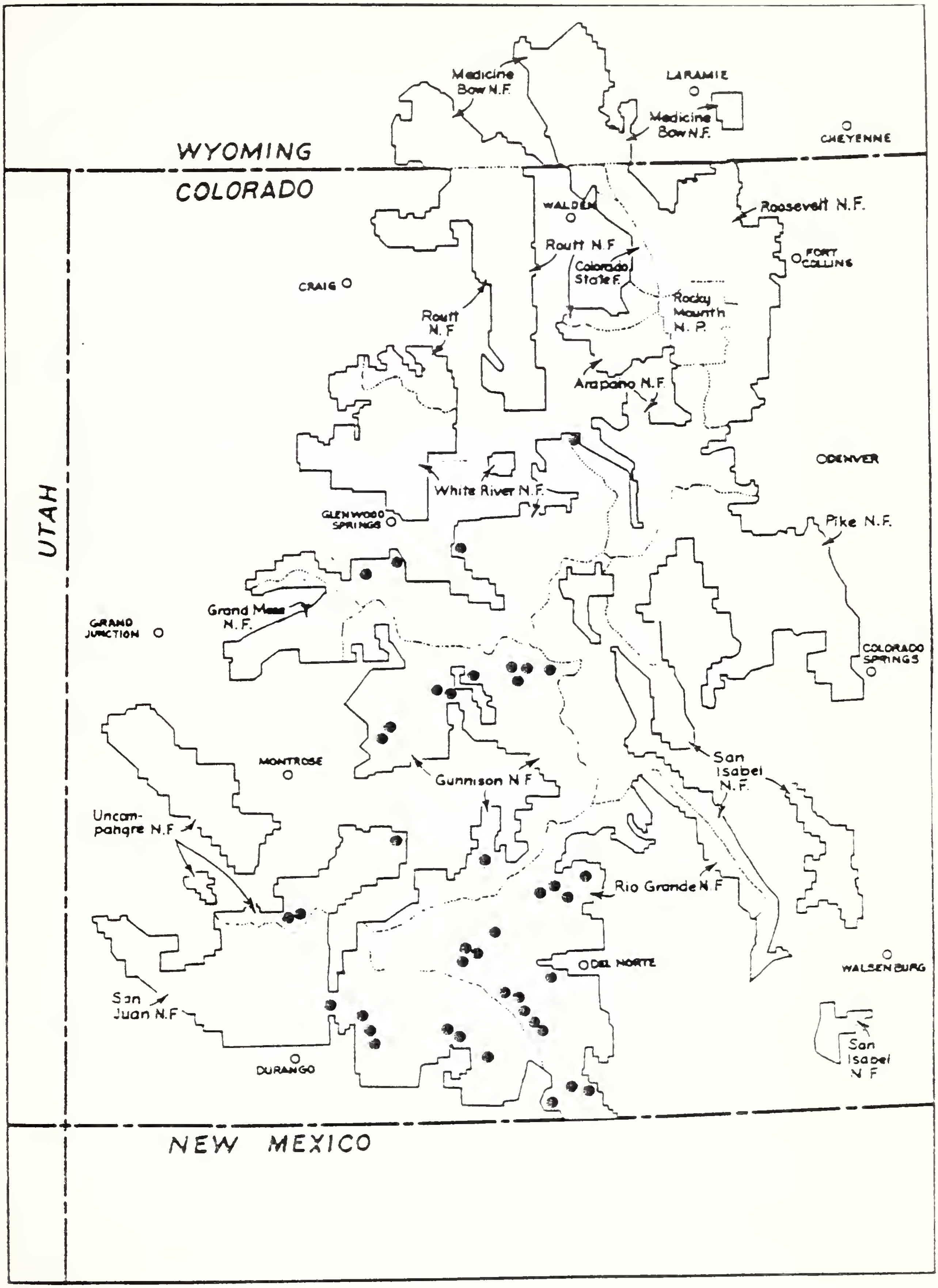
MATERIALS AND METHODS

Sites for intensive survey were selected from those recommended by silviculturalists on six National Forests (Gunnison, Uncompahgre, San Juan, Rio Grande, White River, and Arapaho) in Colorado. The survey was designed to evaluate spruce-fir stands that are currently or will soon be under intensified management. Forty-one stands (Fig. 3) within 15 Ranger Districts were selected. Legal descriptions of sites sampled are summarized in the Appendix.

Surveys were conducted from mid-summer to early fall, 1978, when the living, yellow brooms on infected trees were readily visible. Survey sites were outlined on standard forest maps (1 inch = 2 miles) and the survey area computed using dot grid overlays. Approximate area surveyed for each site is summarized in the Appendix. Data were taken on one fixed-radius plot (0.1 acre) per square mile. In areas less than five square miles, data were taken on five plots. Plots were established evenly along roads on the uphill side and along triangular paths through roadless areas.

FIGURE 3

Sites on selected National Forests in Colorado sampled for conifer broom rust (● = denotes sites sampled).


Medicine Bow N.F.
LARAMIE
Medicine Bow N.F.
CHEYENNE
WYOMING
COLORADO
WALDEN
Roosevelt N.F.
Routt N.F.
FORT COLLINS
Colorado State F.
CRAIG
Rocky Mountain N.P.
Routt N.F.
Arapaho N.F.
DENVER
White River N.F.
GLENWOOD SPRINGS
Pike N.F.
UTAH
Grand Mesa N.F.
GRAND JUNCTION
COLORADO SPRINGS
MONTROSE
Gunnison N.F.
San Isabel N.F.
Uncompahgre N.F.
Rio Grande N.F.
DEL NORTE
WALSENBURG
San Juan N.F.
DURANGO
San Isabel N.F.
NEW MEXICO

The following data were collected within each plot: tree species (Engelmann spruce, subalpine fir, or white fir) and total number of live and dead broomed and non-broomed trees within each of four size-class categories. 1/

The following information was collected for each broomed plot tree: species, size class, crown class, rust rating, 2/ total number of live and dead brooms per tree plus those brooms within one foot of the bole, presence of bole cankers, number of brooms associated with these bole cankers, and presence of spike and broken tops. A variable plot was established with a 10 BAF prism at the center of each fixed plot to determine basal area. Approximate slope, aspect, and altitude were recorded at each plot.

Data were summarized for each survey site, Ranger District, and National Forest. Analysis included T-tests comparing (1) tree size class with average rust rating and (2) tree condition (live or dead) with average rust rating. Differences in frequency of rust ratings in each size class were tested using a 6x4 Chi Square Contingency Table. Correlation analyses were used to compare size class with rust rating.

1/ Size-class categories:

Seedling - less than 1" DBH
Sapling - 1 to 4.9" DBH
Pole - 5 to 8.9" DBH
Sawtimber - 9" DBH and greater.

2/ Intensity of rust infection was evaluated on the basis of number of brooms within each third of the crown. The rating for each crown-third was recorded 0-2 (0 indicated no brooms, 1 indicated light infection - one or two brooms; 2 indicated heavy infection-three or more brooms). Scores for each third were totaled to get a numerical rating. This rating scheme was based on the system developed by Hawksworth (2) for dwarf mistletoes.

RESULTS

Over 20,000 spruce and fir on 301 plots were sampled for broom rust infection [3/] on six National Forests in Colorado. Incidence is summarized by tree size class for spruce and fir in Tables 1 and 2 respectively. Although the various size classes were evenly represented within the sampled spruce, over 75% of the fir sampled were seedlings and saplings. About 7% of the spruce and 6% of the fir sampled were dead. Dead trees made up a greater percentage of the larger size classes.

Broom rust was found in trees of all size classes. Disease incidence was usually greater on pole- and sawtimber-size trees; however, seedlings and small-diameter saplings were occasionally infected (Fig. 2-D). The total percentage of spruce infected was greater than true fir. The percentage of broomed dead trees was greater than the percentage of broomed live trees for both spruce and fir.

Average rust rating was a measure of infection intensity. Live, diseased spruce trees had a lower average rust rating for all size classes than dead trees (Table 1). Statistical analyses indicated no significant differences in average rust rating among the four size classes. Analyses did show, however, that dead Engelmann spruce trees had significantly ($P = 0.01$) higher average rust ratings than live spruce. No differences were found for live and dead fir trees.

Disease incidence for each National Forest sampled is summarized in Tables 3 and 4. Summaries indicate that percentage rust infection on spruce and fir varied widely among the sites sampled. Several of the sites sampled did not have either spruce or fir broom rust.

Spruce broom rust was most common on the Gunnison, San Juan, and Rio Grande National Forests. The East Florida site on the Pine Ranger District (San Juan National Forest) had the greatest percentage (29%) of rust-infected spruce. Incidence was also high on the Del Norte Ranger District (Rio Grande National Forest) where over 23% of the sample trees on one site (Thunder #1) were infected.

3/ Infection was based solely on the presence of rust-incited brooms. This method may have underestimated actual infection rates because some recently-infected trees may not have developed conspicuous brooms (8).

TABLE 1. Engelmann spruce broom rust incidence and average rust rating by tree size class on selected National Forests in Colorado 1/

	Total Trees						Broomed Trees						Ave. Rust Rating 5/	
Size Class 2/	Total	Percent	Live	Percent	Dead	Percent	Total	Percent	Live	Percent 3/	Dead	Percent 4/	Live	Dead
Seedling	2810	27.7	2749	97.8	61	2.2	7	0.2	6	0.2	1	1.6	1.3	2.0
Sapling	3009	29.6	2735	90.9	274	9.1	45	1.5	33	1.2	12	4.4	1.4	1.7
Pole	2202	21.7	2014	91.5	188	8.5	114	5.2	90	4.5	24	12.8	1.5	1.6
Sawtimber	2139	21.0	1968	92.0	171	8.0	261	12.2	221	11.2	40	23.4	1.5	2.2
Totals	10,160	100.0	9466	93.2	694	6.8	427	4.2	350	3.7	77	11.1	1.5	1.9

1/ Data obtained from the following National Forests: Gunnison, Uncompahgre, San Juan, Rio Grande, White River, and Arapaho

2/ Size class categories: Seedling (less than 1 inch DBH); Sapling (1-4.9 inches DBH); Pole (5-8.9 inches DBH); Sawtimber (over 9 inches DBH).

3/ Percent of total live trees.

4/ Percent of total dead trees.

5/ Based on a six-class rating system (see page 13). The average values are for broomed trees only.

TABLE 2. True fir broom rust incidence and average rust rating by tree size class on selected National Forests [1/]

Size Class [2/]	Total Trees						Broomed Trees						Ave. Rust Rating [5/]	
	Total	Percent	Live	Percent	Dead	Percent	Total	Percent	Live	Percent [3/]	Dead	Percent [4/]	Live	Dead
Seedling	5042	50.4	4950	98.2	92	1.8	24	0.5	22	0.4	2	2.2	1.4	2.0
Sapling	2556	25.5	2312	90.4	244	9.6	49	1.9	45	1.9	4	1.6	1.8	1.3
Pole	1452	14.5	1316	90.6	136	9.4	73	5.0	72	5.5	1	0.7	1.8	1.0
Sawtimber	957	9.6	843	88.1	114	11.9	89	9.3	81	9.6	8	7.0	1.6	1.8
Totals	10,007	100.0	9421	94.1	586	5.9	235	2.3	220	2.3	15	2.6	1.7	1.6

1/ Data obtained from the following National Forests: Gunnison, Uncompahgre, San Juan, Rio Grande, White River and Arapaho.

2/ Size class categories: Seedling (less than 1 inch DBH): Sapling (1-4.9 inches DBH); Pole (5-8.9 inches DBH); Sawtimber (over 9 inches DBH).

3/ Percent of total live trees.

4/ Percent of total dead trees.

5/ Based on a six-class rating system (see page 13). The average values are for broomed trees only.

TABLE 3. Incidence and characteristics of Engelmann spruce broom rust on selected National Forests in Colorado.

National Forest [1]	Number of Trees Examined			Number of Trees Broomed			Percent Broomed	Ave. Number Brooms/Tree [2]			Ave. Number Brooms/Tree Within 1 foot of the Bole [2]		
								Live Trees		Dead Trees	Live Trees		Dead Trees
	Live	Dead	Total	Live	Dead	Total		Live Brooms	Dead Brooms	Brooms	Live Brooms	Dead Brooms	Brooms
Gunnison	3910	201	4111	161	22	183	4.4	1.9	1.8	5.8	0.8	0.8	2.7
Uncompahgre	436	25	461	2	0	2	0.4	0.5	0.5	-	0.0	0.0	-
San Juan	144	2	146	6	0	6	4.1	1.3	2.5	-	0.2	0.0	-
Rio Grande	4405	409	4814	180	55	235	4.9	1.9	1.4	3.8	0.8	0.5	1.4
White River	337	31	368	0	0	0	0.0	-	-	-	-	-	-
Arapaho	234	26	260	1	0	1	0.5	0.0	1.0	-	0.0	0.0	-
Totals	9466	694	10160	350	77	427	4.2	1.8	1.6	4.4	0.8	0.6	1.7

1/ The following ranger districts were sampled: Gunnison: Taylor River, Paonia, & Cebolla. Uncompahgre: Ouray. San Juan: Pagosa, Piedra, & Pine. Rio Grande: Conejos, Saguache, Alamosa, Del Norte, & Creed. White River: Rifle & Sopris. Arapaho: Dillon.

2/ Averages include broomed trees only.

TABLE 4. Incidence and characteristics of true fir broom rust on selected National Forests in Colorado.

National Forest [1]	Number of Trees Examined			Number of Trees Broomed			Percent Broomed	Ave. Number Brooms/Tree [2]			Ave. Number Brooms/Tree Within 1 foot of the Bole [2]		
								Live Trees		Dead Trees	Live Trees		Dead Trees
	Live	Dead	Total	Live	Dead	Total		Live Brooms	Dead Brooms	Brooms	Live Brooms	Dead Brooms	Brooms
Gunnison	2134	76	2210	5	2	7	0.3	0.6	0.4	3.5	0.2	0.4	1.5
Uncompahgre	736	46	782	3	0	3	0.5	0.6	0.3	-	0.0	0.0	-
San Juan	1414	60	1474	194	10	204	13.8	1.4	2.2	1.7	0.2	0.2	0.1
Rio Grande	2577	130	2707	8	2	10	0.4	1.1	0.6	7.0	0.5	0.1	4.5
White River	1583	126	1709	10	1	11	0.6	0.6	1.2	1.0	0.3	0.5	0.0
Arapaho	977	148	1125	0	0	0	0.0	-	-	-	-	-	-
Totals	9421	586	10007	220	15	235	2.3	1.4	2.1	2.7	0.2	0.2	0.9

1/ The following ranger districts were sampled: Gunnison: Taylor River, Paonia, & Cebolla. Uncompahgre: Ouray. San Juan: Pagosa, Piedra, & Pine. Rio Grande: Conejos, Saguache, Alamosa, Del Norte, & Creede. White River: Rifle & Sopris. Arapaho: Dillon.

2/ Averages include broomed trees only.

Fir broom rust was common on white fir on the San Juan National Forest. Incidence was greatest at the Bear Creek site of the Pine Ranger District and the Dutton Ditch #1 site of the Piedra Ranger District. Infection percentage on sampled trees at these two sites was approximately 42% and 37%, respectively.

Data summaries on the average number of brooms per infected tree and those brooms within one foot of the bole are also included in Tables 3 and 4. The average number of brooms per tree were greater on dead spruce and fir trees than on live trees. Approximately 40% and 20% of the brooms were within one foot of the bole on infected spruce and fir trees, respectively.

Associations between rust brooms and bole cankers on diseased spruce and fir are summarized in Table 5. Less than half of the live, broomed spruce had associated bole cankers. However, over 77% of the dead, broomed trees had bole cankers. Over 50% of the live, diseased fir trees had bole cankers, whereas, only 26% of the dead, broomed fir trees had bole cankers. Many of the brooms on live and dead spruce and fir trees were in close proximity to bole cankers.

Table 6 summarizes relationships between spike tops and broken tops and broom rust infection. About 7% of the broomed spruce sampled had spike tops and 2% had broken tops. Only 2% of the diseased fir had spike tops and 1% had broken tops.

DISCUSSION

This survey provides insight into the current broom rust disease situation in selected Engelmann spruce and true fir stands in Colorado. Survey sites were selected because of their potential importance in fiber production. Since spruce and fir represent the majority of timber cut annually in Colorado (13), information on disease incidence and distribution is needed to develop management guidelines.

The wide range in disease incidence found among sampled stands may indicate epidemiological differences. Factors that may influence broom rust disease levels include: (1) abundance of the alternate host, which affects inoculum quantity and distribution; (2) stand composition, which influences host target area (amount of tissue susceptible to infection); (3) microclimatic conditions, which directly affects infection processes; and (4) variation in host susceptibility.

TABLE 5. Association of bole cankers with witches' brooms on rust-infected Engelmann spruce and true fir from selected National Forests in Colorado.

Species	National Forest	Number and Percent of Broomed Trees with Bole Cankers 1/				Average Number of Brooms Associated with Bole Cankers 2/		
						Live Trees		Dead Trees
		Live Trees	%	Dead Trees	%	Live Brooms	Dead Brooms	All Brooms
Engelmann Spruce	Gunnison	49	36.6	9	64.3	0.8	0.9	3.4
	Uncompahgre	12	41.4	6	75.0	0.8	1.0	2.7
	San Juan	4	67.7	0	0.0	1.8	2.8	-
	Rio Grande	89	49.4	45	81.8	1.4	1.0	2.5
	White River	0	0.0	0	0.0	-	-	-
	Arapaho	1	100.0	0	0.0	0.0	1.0	-
	Totals	155	44.3	60	77.9	1.1	1.0	2.7
True Fir	Gunnison	0	0.0	1	50.0	-	-	2.0
	Uncompahgre	3	100.0	0	0.0	0.7	0.3	-
	San Juan	103	53.1	3	30.0	0.7	0.8	1.3
	Rio Grande	4	50.0	0	0.0	0.8	0.8	-
	White River	3	30.0	0	0.0	0.7	0.3	-
	Arapaho	0	0.0	0	0.0	-	-	-
	Totals	113	51.4	4	26.7	0.7	0.8	1.5

1/ Percentages of total broomed trees that have bole cankers associated with brooms.

2/ Averages include only broomed trees with associated bole cankers. Associated brooms include those in close proximity to bole cankers.

TABLE 6. Relationships between spike topped and broken topped Engelmann spruce and true fir and broom rust infection. 1/

Species	National Forest	Number of Trees with Spike Tops 2/		Percent of Broomed Trees with Spike Tops	Number of Trees with Broken Tops		Percent of Broomed Trees with Broken Tops
		With Brooms	Without Brooms		With Brooms	Without Brooms	
Engelmann Spruce	Gunnison	8	18	5.4	4	16	2.7
	Uncompahgre	5	9	13.5	0	8	0.0
	San Juan	0	0	0.0	0	0	0.0
	Rio Grande	18	22	7.7	4	7	1.7
	White River	0	4	0.0	0	3	0.0
	Arapaho	0	1	0.0	0	0	0.0
	Totals	31	54	7.3	8	34	1.9
True Fir	Gunnison	1	4	14.3	0	8	0.0
	Uncompahgre	1	6	33.3	0	16	0.0
	San Juan	3	10	1.5	3	11	1.5
	Rio Grande	0	8	0.0	0	3	0.0
	White River	0	8	0.0	0	8	0.0
	Arapaho	0	16	0.0	0	6	0.0
	Totals	5	52	2.2	3	52	1.3

1/ Infection was evaluated on the basis of presence or absence of brooms.

2/ Spike tops are defined as dead tops (without foliage) which are still intact (see Fig. 1).

Disease variability on different tree size classes is an important stand management consideration. Greater disease incidence and higher average rust ratings were found on pole- and sawtimber-size trees. Mature stands are probably more susceptible to infection than younger stands because they provide more target area for basidiospores (8). However, mature stands may not be damaged by any amount of infection under managed conditions. Although young stands provide less target for infection, much of this target is near the merchantable bole so that greater stand impact due to growth loss and mortality will occur. Broom rust also has longer to develop and cause adverse effects in younger trees.

A larger percentage of spruce trees were infected with broom rust than fir. Stand composition, alternate host populations, and host susceptibility may have influenced infection rates. However, a greater proportion of pole- and sawtimber-size spruce trees were sampled; whereas, many of the sampled fir were from smaller size classes. Differences in size classes sampled may account for differences in disease incidence between species.

Melampsorella caryophyllacearum was most common on white fir on the San Juan and Rio Grande National Forests. There was much less disease on subalpine fir from National Forests (Gunnison, Uncompahgre, White River, and Arapaho) farther north. The non-randomness of stand selection may have partially accounted for the differences.

Infection intensity was usually greater on dead trees than on live trees within similar size classes. Dead broomed trees had more conspicuous bole cankers than live trees. Previous reports (6, 7) have indicated that tree mortality may result from broom rust infection; however, these reports need to be substantiated. Other agents may have hastened or caused tree mortality. Quantitative data on association of insects and other pathogens with broom rust infection were not taken during our survey. However, evidence of spruce beetle (*Dendroctonus rufipennis* (Kirby) activity on recently-killed Engelmann spruce was common. Fir engraver (*Scolytus ventralis* LeConte) and western balsam bark beetle (*Dryocoetes confusus* Swaine) galleries were also found on many dead white fir and subalpine fir with broom rust. The Indian paint fungus (*Echinodontium tinctorium* (E. & E.) E. & E.) and root disease caused by *Armillariella mellea* (Vahl. ex Fr.) Karst, were commonly associated with rust-infected white fir. The role of these other organisms in causing tree mortality is unknown. Rust-weakened trees may be more susceptible to bark beetles and other pathogens which ultimately cause mortality.

Mortality due directly or indirectly to broom rust may not be important in spruce-fir stands (8). Stocking in young stands most

likely will not be seriously affected by scattered tree mortality because these stands are commonly overstocked. Occasional mortality may in fact result in increased stand productivity by releasing understory trees.

Broom rust infections may provide infection courts for canker and decay fungi (9, 12). Necrotic plant tissues distal to rust brooms are often the result of invasion by canker fungi. Locally systemic rust mycelium may also induce girdling which results in spike tops and branch flagging (8). Broken tops associated with broom infections near the bole are indicators of decay (4). Less than 8% of the broomed spruce and fir trees sampled had spike or broken tops. However, non-broomed, infected trees may have accounted for a large percentage of the spike tops and broken tops encountered in some stands.

Percentage of broom rust infection may have little relation to potential silvicultural treatment of stands. Trees with a few small branch brooms may not be seriously impacted by the disease. Only infections that are close to the bole or numerous large branch brooms may cause serious growth effects or reduce wood quality (8). Our survey indicated that on some trees many brooms were near the bole and associated with cankers. These trees probably present the greatest "risk" to future stand productivity. Trees with light branch infections probably need not be discriminated against in silvicultural treatments.

RECOMMENDATIONS

The following silvicultural guides are listed in order of priority for treatment of rust-infected stands:

I. <u>Commercial Entries</u> (maximum cutting cycle - 30 years)

1. Remove trees with spike tops or broken tops (maintain sufficient number of snags for wildlife).
2. Remove all broomed trees with symptoms of bark beetle attack, decay, and root disease.
3. Remove trees with one or more bole cankers which girdle at least 1/3 of the stem circumference.

4. Remove trees with one or more dead brooms and two or more live brooms within one foot of the bole.

5. Remove broomed trees with a rust rating of 3 or greater.

II. Precommercial Entries (thinnings, Timber Stand Improvement)

1. Remove trees with spike tops or broken tops.

2. Remove all infected trees while maintaining adequate stocking levels. If minimum stocking guides cannot be met, remove infected trees using the priority system described for commerical entries.

III. Recreation Sites - use the guidelines described for commerical entries with the following modifications:

1. Removal of hazardous trees and branches have the highest priority.

2. Remove all dead trees - wildlife trees should not be left if they pose a hazard to recreationists.

3. Maintain as many live trees as possible. Remove only those trees that are hazardous.

4. Use the guidelines described by Johnson and James (12) for selecting hazardous trees.

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APPENDIX

Descriptions of sites and approximate areas sampled for incidence of spruce and fir broom rust in Colorado.

I. Gunnison National Forest

A. Taylor River Ranger District

1. Crested Butte: Section 25, T. 13 S., R. 86 W.; Section 30, T. 13 S., R. 85 W. (ca 1.8 sq. mi.); 5 plots.

2. Splains Gulch: Sections 12 and 13, T. 14 S., R. 87 W. (ca 1.0 sq. mi.); 5 plots.

3. Flag Creek: Sections 35 and 36, T. 13 S., R. 84 W., Section 2, T. 14 S., R. 84 W. (ca 3.0 sq. mi.); 10 plots.

4. Rocky Point: Sections 25, 26, 35, and 36, T. 14 S., R. 83 W. (ca 2.5 sq. mi.); 5 plots.

5. Wheelbarrow Gulch: Sections 10 and 15, T. 14 S., R. 83 W. (ca 1.8 sq. mi.); 5 plots.

6. Texas Creek: Sections 10 and 11, T. 14 S., R. 81 W. (ca 1.3 sq. mi.); 7 plots.

B. Paonia Ranger District

1. Kebler Pass: Sections 3, 4, and 9, T. 14 S., R. 87 W. (ca 2.0 sq. mi.); 5 plots.

2. Dyer Creek #1: Section 33, T. 51 N., R. 5 W. (ca 0.5 sq. mi.); 5 plots.

3. Dyer Creek #2: Sections 4 and 5, T. 51 N., R. 5 W. (ca 0.8 sq. mi.); 5 plots.

C. Cebolla Ranger District

1. Blue Park: Sections 1, 4, 5, 7, 9, 12, 13, 14, 15, 16, 22, 27, and 34, T. 44 N., R. 1 E.; Section 33, T. 45 N., R. 1 E. (ca 10.5 sq. mi.); 35 plots.

2. Alpine Plateau: Sections 17, 20, 29, and 32, T. 46 N., R. 4 W.; Section 5, T. 45 N., R. 4 W. (ca 4.0 sq. mi.); 11 plots.

II. Uncompahgre National Forest

A. Ouray Ranger District

1. Alta Lakes: Sections 22 and 23, T. 42 N., R. 9 W. (ca 0.8 sq. mi.); 5 plots.

2. Gold Creek: Sections 21 and 28, T. 42 W., R. 9 W. (ca 1.5 sq. mi.); 8 plots.

III. San Juan National Forest

A. Pagosa Ranger District

1. Mill Creek: Sections 8, 9, 17, and 18, T. 35 N., R. 1 E. (ca 4.0 sq. mi.); 12 plots.

B. Piedra Ranger District

1. Dutton Ditch #1: Sections 9, 10, and 16, T. 36 N., R. 2 W. (ca 2.8 sq. mi.); 5 plots.

2. Dutton Ditch #2: Section 16, T. 36 N., R. 2 W. (ca 0.5 sq. mi.); 6 plots.

C. Pine Ranger District

1. Beaver Meadows: Sections 5 and 8, T. 35 N., R. 5 W. (ca 1.8 sq. mi.); 8 plots.

2. Bear Creek: Section 36, T. 36 N., R. 6 W. (ca 1.0 sq. mi.); 5 plots.

3. East Florida: Sections 19 and 20, T. 37 N., R. 7 W. (ca 1.3 sq. mi.); 5 plots.

4. Vallecito: Section 21, T. 37 N., R. 6 W. (ca 0.8 sq. mi.); 6 plots.

IV. Rio Grande National Forest

A. Conejos Ranger District

1. Dry Lake: Sections 4, 11, and 15, T. 33 N., R. 6 E. (ca 1.8 sq. mi.); 5 plots.

2. Notch: Sections 18 and 19, T. 34 N., R. 5 E. (ca 1.5 sq. mi.); 8 plots.

3. Chama: Sections 4 and 5, T. 32 N., R. 4 E.; Sections 32 and 33, T. 33 N., R. 4 E. (ca 1.3 sq. mi.); 7 plots.

B. Saguache Ranger District

1. Fence: Sections 29 and 30, T. 43 N., R. 5 E. (ca 0.8 sq. mi.); 5 plots.

2. California Mountain: Sections 8, 17, and 18, T. 43 N., R. 4 E. (ca 2.3 sq. mi.); 5 plots.

3. Lookout Mountain: Sections 35 and 36, T. 44 N., R. 4 E. (ca 0.8 sq. mi.); 5 plots.

4. Mill Creek: Sections 20 and 29, T. 44 N., R. 6 E. (ca 0.8 sq. mi.); 5 plots.

C. Alamosa Ranger District

1. Globe Creek West: Section 7, T. 36 N., R. 4 E. (ca 0.8 sq. mi.); 5 plots.

2. Globe Creek East: Section 8 and 17, T. 36 N., R. 4 E. (ca 1.3 sq. mi.); 5 plots.

D. Del Norte Ranger District

1. Thunder #1: Sections 29 and 33, T. 38 N., R. 2 E. (ca 1.3 sq. mi.); 5 plots.

2. Thunder #2: Section 33, T. 38 N., R. 2 E. (ca 0.5 sq. mi.); 5 plots.

3. Five Mile: Sections 9, 10, 15, 22, 23, and 26, T. 37 N., R. 3 E. (ca 4.8 sq. mi.); 14 plots.

4. Wolf: Sections 8, 16, and 17, T. 39 N., R. 4 E. (ca 2.8 sq. mi.); 7 plots.

E. Creede Ranger District

1. Hanson's Mill: Section 23, T. 41 N., R. 2 E. (ca 1.0 sq. mi.); 15 plots.

2. U. L. Ivy: Sections 21, 27, 28, 33, and 34, T. 40 N., R. 1 W. (ca 2.8 sq. mi.); 5 plots.

3. Middle Creek: Sections 12, 13, and 14, T. 39 N., R. 2 W.; Section 31, T. 40 N., R. 1 W. (ca 2.8 sq. mi.); 11 plots.

V. White River National Forest

A. Rifle Ranger District

1. Reservoir Park: Sections 19, 30, and 31, T. 8 S., R. 90 W. (ca 2.0 sq. mi.); 7 plots.

B. Sopris Ranger District

1. Basalt Mountain: Section 19, T. 7 S., R. 86 W. (ca 0.5 sq. mi.); 5 plots.

2. Sunlight Peak: Section 19, T. 7 S., R. 89 W. (ca 1.0 sq. mi.); 5 plots.

VI. Arapaho National Forest

A. Dillon Ranger District

1. Sheep Mountain: Sections 22, 23, 26, and 35, T. 2 S., R. 81 W. (ca 2.5 sq. mi.); 9 plots.

Total area surveyed ca 78.9 sq. mi.; 301 plots.